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Inorganic Bonding of Semiconductor Strain Gages

An improved method of bonding semiconductor strain gages to metallic force collectors of transducers has been developed and evaluated. This innovation involves the use of inorganic bonding materials instead of the conventional organic adhesives normally employed for this purpose. Organic epoxies have excellent mechanical properties when they are used within their design limits. When they are exposed to ultra-high vacuum, however, outgassing occurs, and when their operating temperatures rise above 350°F, hysteresis develops and the transducer becomes unstable. Consequently, the replacement of the organic adhesives with inorganic bonding materials appeared to be a way to minimize the outgassing and to improve the electrical and mechanical properties of the semiconductor strain-gage transducers in high-vacuum and high-temperature operations. Two basic methods were examined: (1) the use of an inorganic substance, such as glass, as the bonding material; and (2) the forming of a metallic bond between the strain gage and the substrate.

In developing the first method, a ceramic-type glass with a relatively low melting point was found to be the best material because its firing-temperature range of 425° to 450°C is considerably lower than that of vitreous glasses. Further, it is readily adaptable to conventional methods of attaching leads to silicon. Because the devitrifying ceramic glass, after it has been cooled, can be reheated to relatively high temperatures without remelting, the sensing element of the transducer has much higher temperature potential than one with which organic adhesives have been used. When this sensing element is used in conjunction with an all-welded transducer housing and high-

temperature auxiliary hardware, for example, it is possible to extend the operating temperature range of the silicon strain-gage transducer to 800°F. The development of a piezoresistive transducer of this type for high-temperature operation is very desirable.

The second method investigated was the metallic or eutectic bond. Establishing such a bond between the silicon strain gage and the force-collecting substrate involves the use of a p-n junction to isolate the diffused strain gage from the silicon substrate, thus forming the strain-sensing portion of the silicon device. The substrate, in turn, is eutectically bonded to the metallic force collector. Both the metallic and silicon substrates are coated with gold; and the sensor and the collector are heated to a temperature above 370°C, which causes the interface to melt. The dissolved silicon redeposits on the single crystal substrate during subsequent cooling, and an intermetallic bond results. This method of bonding is difficult to accomplish, because a uniform and complete bond over the entire area of the strain gage is necessary for the effective transmission of strain to the diffused sensing elements, and because the relatively thin sensor is very fragile.

The ceramic-glass-bonding technique has been very successful, and has made practical the construction of unique force collectors with many desirable features. The deleterious outgassing that is characterized with organic bonds is minimized, hysteresis is reduced, and repeatability is improved. In addition, the inorganic glass is not as susceptible as epoxies to degradation by intense radiation. The metallic bonding technique is difficult, but is worthy of further investigation. Its advantages are essentially those de-

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scribed for the glass-bonding method, and, in addition, it is likely that even less outgassing will occur in ultra-high vacuum environments.

Notes:

1. The bonding methods described in this document are applicable for use in hard vacuums, such as those of high-temperature, RF vacuum tubes.
2. The following documentation may be obtained from:

Clearinghouse for Federal Scientific
and Technical Information
Springfield, Virginia 22151
Single document price \$3.00
(or microfiche \$0.65)

Reference: NASA CR-100015 (N69-19138),
The Development and Evaluation of an
Inorganic Bonding Method for Semi-
conductor Strain Gages for Space and
Ultra High Vacuum Applications

Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

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